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ScienceDirect

Energy Procedia 100 (2016) 22 – 25

Energy Procedia

3rd International Conference on Power and Energy Systems Engineering, CPESE 2016, 8-12 September 2016, Kitakyushu, Japan

Optimum Ratio of Chicken Manure and Napier Grass in Single Stage Anaerobic Co-digestion

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Abstract

This study examined an optimum ratio of chicken manure to Napier grass (*Pennisetum purpureum*, Schum.) for single stage anaerobic digestion in batch reactor. Carbon to nitrogen (C/N) ratio of chicken manure was 8.22 and Napier grass was 39.35. The anaerobic digestion experiments for 5 ratios of chicken manure to Napier grass of 1:0, 3:1, 1:1, 1:3, and 0:1 were conducted using hydraulic retention time of 48 days and total solids were controlled at 2%. The mixed organic materials of chicken manure to Napier grass of 1:1 achieved a high methane percentage of 64.4% and also remained stable for anaerobic digestion. Single material in anaerobic digestion: chicken manure or Napier grass did not yield maximum methane production. C/N ratio of chicken manure was not suitable for anaerobic digestion because excessive nitrogen could inhibit the growth of methane-forming bacteria. Anaerobic digestion of Napier grass presented low stability due to high VFA accumulation in the system from hydrolysis of cellulose in the grass.

Peer-review under responsibility of the organizing committee of CPESE 2016

Keywords: Biogas production; Anaerobic co-digestion; Chicken manure; Napier grass

1. Introduction

Biogas is an attractive renewable energy; especially as an alternative energy in agricultural area. Agriculture wastes, i.e., crop wastes and livestock manures, are organic matters which can, through certain processes, turn to biogas by anaerobic digestion. Recently, Thailand's government has promoted using renewable energy from biogas particularly in livestock farms [1]. Biogas potential of livestock manures from swine, cow, and chicken yield biogas production of 0.10-0.38, 0.26-0.28, and 0.40-0.60 m^3kg^{-1}, respectively [2,3]. Chicken manure shows higher biogas production potential than the others. In addition, there is a factor that affects biogas production i.e., carbon to nitrogen (C/N) ratio because a low C/N ratio causes excess nitrogen remaining in an anaerobic system [4]. The excess nitrogen turns to ammonia which inhibits the growth of methane-forming bacteria. Suggested C/N proportion for biogas fermentation is 20-30 while C/N of chicken manure is about 10. Thus, co-digestion between two materials, low and high C/N ratios, would result in the proper C/N ratio. There is a report of C/N of Napier grass

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Peer-review under responsibility of the organizing committee of CPESE 2016
doi:10.1016/j.egypro.2016.10.141

which is about 35; this would be a material mixed with chicken manure to achieve the suggested C/N proportion and yield high methane production. Thus, the objective of this study was to examine an optimum ratio of chicken manure to Napier grass (*Pennisetum purpureum*, Schum.), a total solids (TS) was controlled at 2%, and anaerobic digestion was conducted in batch reactor.

2. Materials and methods

2.1. Chicken manure and Napier grass

Chicken manure was collected from layer chicken farm in Khon Kaen, Thailand. A 45-day Napier grass (*Pennisetum purpureum*, Schum.) obtained from a farm in Chumphae District, Khon Kaen was crushed to size range 0.5-2.0 cm. Physical and chemical characteristics of all materials were analyzed (Table 1).

Table 1. Characteristics of chicken manure (CM) and Napier grass (N) in this research.

	Chicken manure (CM)	Napier grass (N)
Total Solids (mg/kg)	658,000	162,983
Volatile Solids (mg/kg)	422,000	143,250
Moisture content (%)	18.49	81.10
C (%)	25.02	48.91
N (%)	3.04	1.23
C/N (%)	8.22	39.35

2.2. Inoculum

Anaerobic seed sludge or inoculum was taken from the end of a biogas fermentation pond where methane-forming bacteria were active at an anaerobic pond in Khon Kaen, Thailand.

2.3. *Batch anaerobic digestion tests*

Five single stage digester tanks of 6 liters with digestion volume of 5 liters were used and each was attached with water-replacement biogas collector. Five experiments of various ratio of chicken manure to Napier grass were 1:0, 3:1, 1:1, 1:3, and 0:1. Total solids were controlled at 2% and hydraulic retention time was 48 days. The ratio of inoculums to co-digesting materials was controlled at 30:70. The mixture in all reactors was stirred by a small paddle at 30 rpm for 15 minutes every 3 hours.

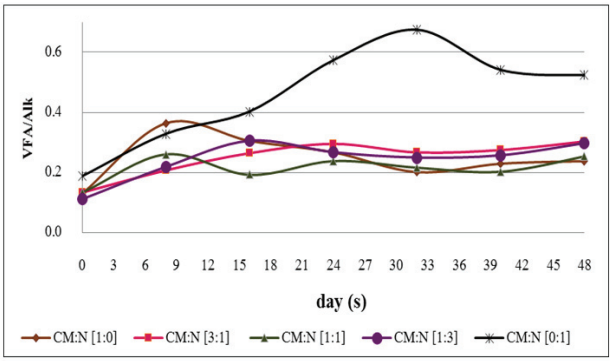
2.4. Analytical methods

Liquid samples were taken from digesters every 7 days. All samples were analyzed for alkalinity (Alk) and volatile fatty acid (VFA) based on the Analytical Standards APHA [5]. Methane percentages were analyzed by Gas Chromatography (Shimadzu, Japan) connected with a thermal conductivity detector. Argon gas was carrier gas at a flow rate of 50 ml/min and injection volume was 1.0 ml. Temperatures of the injector inlet, oven and detector were 150, 250 and 250^{o}C.

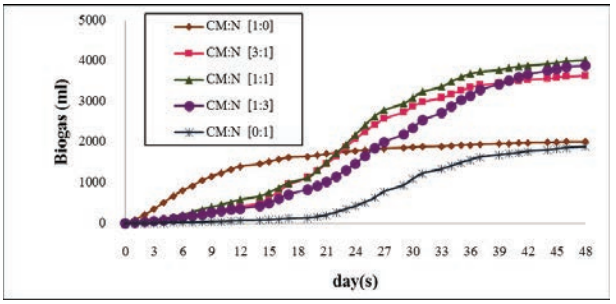
3. Results and Discussion

3.1. Volatile fatty acid (VFA) and alkalinity (Alk)

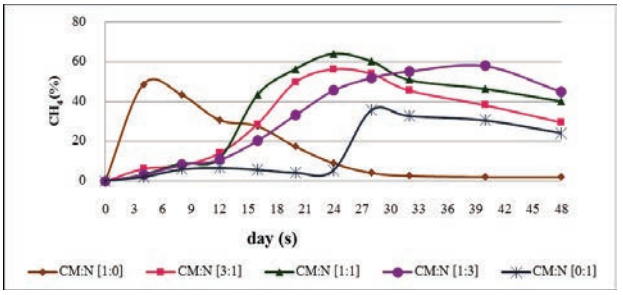
Stability of anaerobic digestion was maintained by VFA/Alk proportion. It should be lower than 0.4 to keep high buffer in the system. The experiment results showed that VFA/Alk of chicken manure to Napier grass of 1:0, 3:1, 1:1, and 1:3 were in the range of 0.1-0.3 while the ratio 0:1 was about 0.67. This tended to lose stability because high ratio of Napier grass took a long time for hydrolysis stage and volatile fatty acid was accumulated in system (Figure 1). It can be seen that co-digestion stabilizes the anaerobic digestion more than using a single material, especially those requiring a long hydrolysis time owing to their high cellulose content, which results in high VFA accumulation [6]. Thus, such materials should be mixed with easily biodegradable substance such as chicken manure.



.Fig. 1. VFA/Alk in anaerobic digestion tank.



(a)



(b)

Fig. 2. (a) Biogas production accumulation; (b) Methane percentage

3.2. Biogas production and methane percentage

Biogas production accumulations throughout the period of the experiments are shown in Figure 2 (a). For the CM:N ratios of 1:0 and 0:1, the biogas production accumulations were lower than the other ratios. Using only chicken manure, ratio 1:0, resulted in rapid biogas accumulation during the first 10 days and then biogas accumulation become steady through the end which was 2000 ml. On the other hand, using only Napier grass i.e., ratio 0:1, showed infinitesimal accumulation of biogas until Day 21. Thereafter, it gradually increased until Day 36 when accumulation became steady, at 1800 ml, until the end. When we considered ratios 3:1, 1:1, and 1:3, the biogas accumulations gradually increased until Day 21, and subsequently increased significantly until Day 40. Finally, at the end of the experiment, biogas production reached 3600, 4000, and 3900 ml, respectively.

Figure 2 (b) shows that maximum methane percentage obtained from the ratio of chicken manure to Napier grass of 1:1. This ratio yielded methane percentage of 64.4 % at Day 24 while ratios of 3:1 and 1:3 yielded methane production of 56.4% and 58.0% at Day 24 and Day 40, respectively. These ratios gave high methane percentages for a longer period. Fermentation without Napier grass, ratio 1:0, presented a high methane percentage of 48.6% at Day 4; then, the production steadily decreased until Day 28 and subsequently the percentage of methane production was infinitesimal. Fermentation without chicken manure, ratio 0:1, presented the maximum methane percentage of

36.0% at Day 28; then the production slightly decreased. This was the result of the high VFA/Alk proportion in the system as discussed previously.

4. Conclusion

Co-digestion between low and high C/N ratios yielded high methane production and also maintained stability of the anaerobic system. The mixed organic materials in anaerobic digestion of chicken manure to Napier grass of 1:1 achieved high methane percentage of 64.4 %. The experiment results also confirmed that anaerobic digestion of a single material: chicken manure or Napier grass did not yield maximum methane production. C/N ratio of chicken manure was not appropriate for anaerobic digestion due to excessive nitrogen in the system, which in turn produced ammonia that inhibits the growth of methane-forming bacteria. Likewise, anaerobic digestion of Napier grass tended to lose its stability due to high VFA accumulation in the system because of hydrolysis of cellulose in the grass.

Acknowledgements

This research was financially supported by Farm Engineering and Automatic Control Technology Research Group, Khon Kaen University.

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